INTRODUCTION TO SINE WAVE OSCILLATORS:

The basic signal generating source in electronic circuits is the oscillator. An oscillator can convert applied DC to AC if certain requirements are met. Oscillators come in different electronic configurations and can be made to produce a variety of frequencies. Some of these configurations are more suitable for generating frequencies in the audio range; some are more suitable for RF (radio frequency) range signals.

There are two major categories of oscillators: 1. Sinusoidal oscillators which produce sine waves. 2. Non-sinusoidal oscillators producing those periodic waveforms other than sine waves. To be discussed are four configurations of sine wave oscillators. These are the Hartley (a variation of this oscillator will also be touched on very briefly), the Colpitts, the RC phase shift, and the crystal oscillator.

OSCILLATOR REQUIREMENTS:

When DC is applied to a free running oscillator (this is an oscillator requiring no external signal to produce an output), AC waveforms will be produced. For the circuit to be operational, the following requirements are necessary. 1. DC voltage must be applied. 2. Regenerative feedback must exist to sustain oscillations. 3. An amplifier must be present in the circuit. 4. There must be a frequency determining device or FDD.

Regenerative feedback occurs when part of the output signal is fed back to the input through the FDD. Depending on the element from which the feedback signal is taken, a 180 degree phase shift may be necessary from output to input to prevent oscillation killing degeneration. If the feedback signal is taken from the collector of a transistor, this phase shift is mandatory. If taken from the emitter, however, no phase shift is necessary. Another way of stating this rule is that a zero degree phase shift around the feedback loop (from the amplifier output through the FDD to the input and back to the output) is a requirement for oscillations to be maintained.

In the following oscillators the FDD will consist of a parallel resonant circuit, an RC phase shift circuit, or a vibrating crystal. The difference in the FDD configurations will largely determine the stability of the oscillator. Stability is a desired characteristic of any oscillator and refers to the circuit's ability to maintain a signal of constant amplitude and frequency. Some FDD's are designed to be tunable for different frequencies. Once tuned, however, the oscillators should be stable.

As will be demonstrated, the amplifier plays the role of a switch which turns on long enough to prevent dampening caused by circuit losses inherent in any oscillator circuit.

PERIODIC WAVEFORMS:

As has been noted, waveforms are either sinusoidal or non-sinusoidal. Examples of non-sinusoidal waveforms include square waves, sawtooth, and pulse type signals. Whatever the waveform's shape, all display certain common characteristics. Voltage amplitude changes are periodic, that is, changes from negative going voltages to positive going voltages occur in repeated cycles. A cycle is one complete change in voltage amplitude from positive to negative and back. The length of time it takes to complete one cycle is the period. Amplitude, period, pulse width, and waveform shape may all be determined directly from the oscilloscope. Frequency, of course, must be calculated.

Additionally, waveforms may be either symmetrical or non-symmetrical. The alternations will be identical in symmetrical waves. Fig. 1 illustrates examples of symmetrical and non-symmetrical waves.

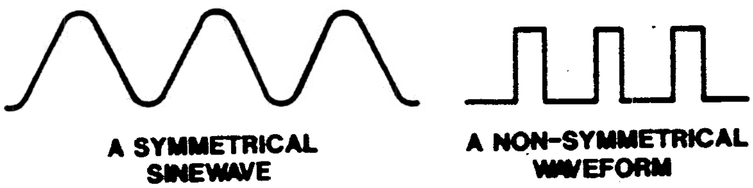


FIGURE 1.

LC NETWORK:

Recall that one of the requirements for an oscillator was a method to determine frequency. One of the common methods utilized is an LC network forming a tank circuit. Capacitors and inductors are connected in parallel and the resonant frequency determined by the size of the components. The operation of the tank circuit is crucial to the comprehension of many oscillator circuits and will be reviewed in some detail.

TANK CIRCUIT OPERATION:

Refer to figures 2 through 7 during the following explanation. Assume that the capacitor C1 is charged as in Fig. 2. A discharge path is formed through inductor L1. As C1 discharges, the current flows through L1, inducing magnetic fields around the inductor. These fields will collapse when C1 has completely discharged, causing current flow to be maintained

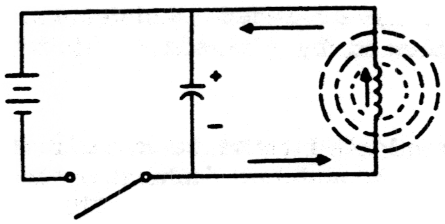


FIGURE 2

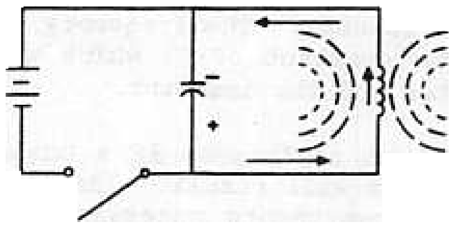


FIGURE 3

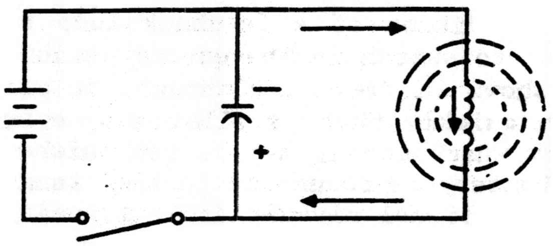


FIGURE 4

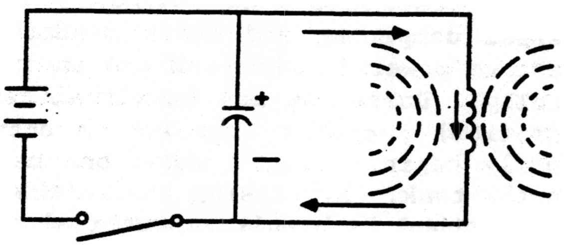


FIGURE 5

FIGURE 6

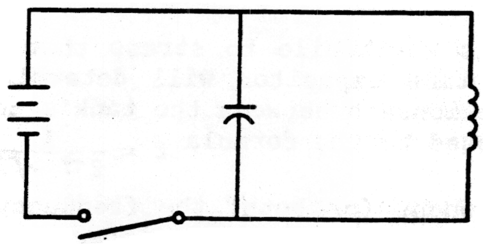


FIGURE 7

and charging C1 as shown in Fig. 3. With the collapse of the fields, C1 will again discharge through L1 once more building fields of flux as demonstrated in Fig. 4. In Fig. 5 the fields collapse when the capacitor has completely discharged. This recharges C1 to the polarity originally seen in Fig. 2 and one cycle has been completed. The resultant change in capacitor voltage can be measured at the top of the tank and displayed on an oscilloscope. The frequency of the sine wave produced is determined by the time constant of C1 which will be influenced by the size of both the capacitor and the inductor.

As has been explained, if a DC voltage is applied to the tank circuit, an AC waveform will result. Ideally, one capacitor and one inductor would be the only components necessary for an operational oscillator. This would be true but for the fact that every circuit has some resistance which uses up power. Thus, the capacitor will, due to power loss during each successive cycle, receive a progressively weaker charge until the point is rapidly reached where no charge is attained. This degeneration of power is called dampening and makes mandatory the addition of a feedback loop to restore power to the tank and an amplifier to switch in the energy periodically. Dampening may be visualized as shown in Fig. 6, although for all practical purposes this action occurs so quickly that oscillations never really begin. Fig. 7 shows one method by which energy may be replenished in the tank. By closing the switch, the battery is connected to the tank. This method is highly impractical in an operational circuit and a transistor is used as the switching device. The shorter the duration of the pulse of energy the better, since power is efficiently conserved. Thus, the amplifier should be designed to operate in class "C". The replenishment of energy to the tank, then, is referred to as regenerative feedback.

It is worthwhile to stress that the time required to charge and discharge the tank capacitor will determine the frequency of the oscillator. The relationship between the tank's components and the frequency may be expressed by the formula $f = \frac{1}{2\pi\sqrt{LC}}$. By changing the value of either component (or both) the frequency may be increased or decreased. Note by increasing the size of either component, the frequency is increased.

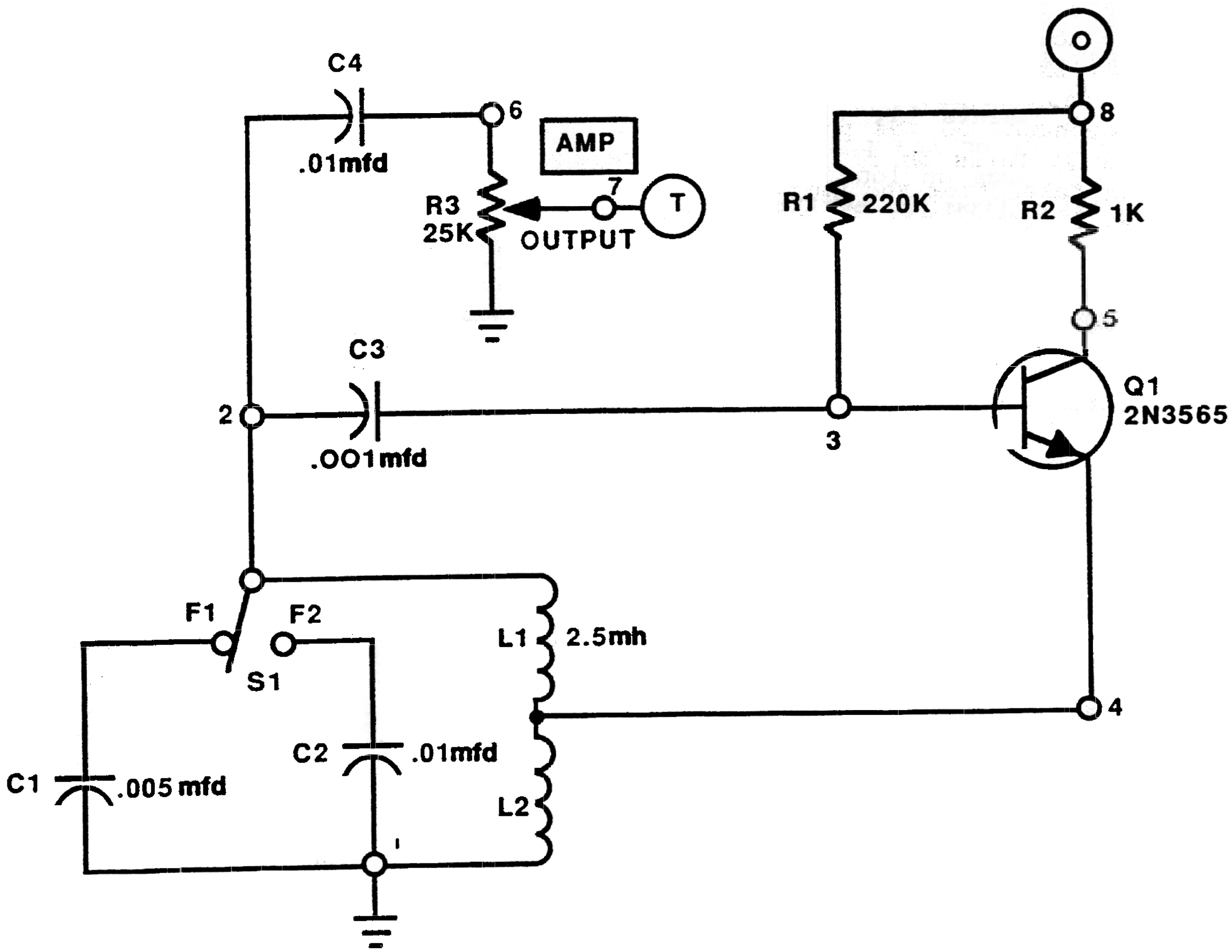
SERIES FED HARTLEY OSCILLATOR:

Refer to Fig. 8 for the following description of the Hartley oscillator. This type of oscillator is capable of providing a wide range of radio frequencies and is easily tuned. Compared to other oscillators, stability is not exceptional. The amplifier is Q1, the FDD is a tank circuit composed of components L1, L2, C1 <u>or</u> C2 which allows for two possible frequencies dependent on the position of S1. The regenerative feedback is developed as Q1 turns on long enough to regenerate tank energy. Since the feedback is taken from the emitter, the 180 degree phase shift from output to input will not be necessary. DC is applied to the circuit whenever trainer power is applied. Thus, the four requirements for oscillations to begin have been met. When Q1 turns on, current flows through L2 and magnetic fields are induced. These fields cut across L1, producing a positive going voltage at the top of the tanks as C1 or C2 charges (this can be seen at TP 2). As Q1 reaches saturation, the capacitors discharge and normal tank circuit action continues to produce oscillations.

It is desirable, at this point, to introduce the concept of <u>base leak bias</u> which is critical to the operation of this and similar circuits. If a digital multimeter is used to measure the voltage at TP 3 (Q1's base), it will be noted that the voltage may have a negative polarity. From prior instruction, it would seem impossible for Q1 to ever turn on with a negative at the base of an NPN transistor. The negative voltage is only apparent and it must be remembered that the DMM will measure the average of voltages at a particular point. This tells us that the voltage on the base of Q1 is negative going more often than it is positive. This fact revolves around this concept of base leak bias. Base leak bias not only controls the class of operation of the amplifier, "C" in this case, it also controls the amount of feedback developed by the oscillator.

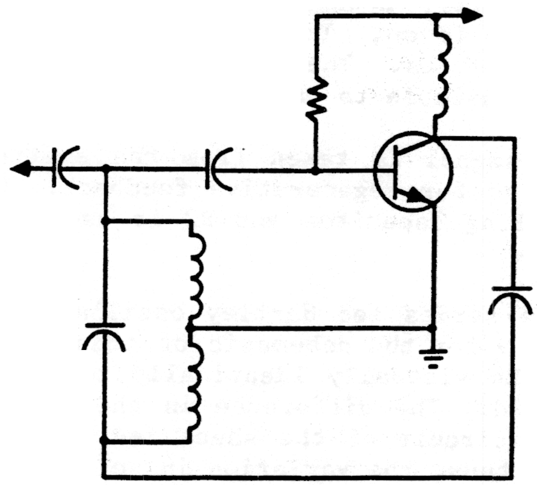
As the term "base leak bias" is not very descriptive (being a holdover from vacuum tubes where it is known as "grid leak bias"). Simply stated, using the Hartley oscillator as a point of reference, base leak bias occurs when C3 charges through Q1 and discharges through R1. As will be explained, the amount of time taken for C3 to partially discharge a specific amount, will determine how long Q1 will be off and, hence, its class of operation. The following will attempt a more detailed explanation.

When power is initially applied to PC 35, Q1 turns on and C3 charges very quickly through the base-emitter junction. C3 will charge negatively on the transistor side and positive on the tank side. Tank action has commenced and a positive going waveform is being developed at TP 2. As tank action continues, the waveform will begin its negative going cycle, and, at some point, will become negative enough (this point will depend on the charge acquired by C3) to cause C3 to begin discharging through R1. With C3 discharging, a negative voltage is developed on the base of Q1, turning the transistor off. As C3 discharges, the tank is causing the signal at TP 2 to go positive which, when C3 has discharged sufficiently, will allow Q1 to turn on for a brief period.



SERIES FED
HARTLEY OSCILLATOR PC35

FIGURE 8



SHUNT FED HARTLEY OSCILLATOR
FIGURE 9

NOTE: The capacitors isolate the tank from all DC current flow.

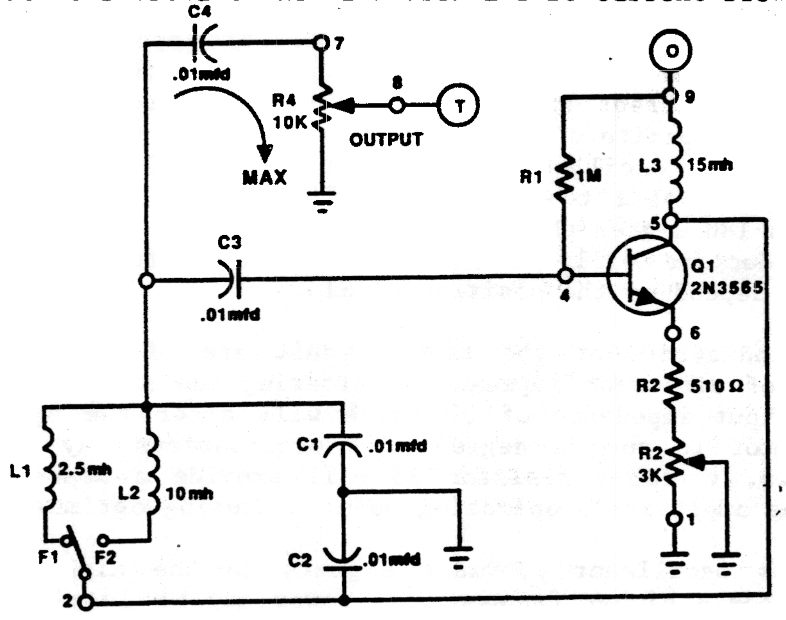


FIGURE 10

Due to the relatively long time constant of the C3, R1 combination with respect to the frequency of oscillations, the capacitor will not be able to discharge much before the transistor again turns on and C3 recharges. The slow discharge will, however, ensure that Q1 stays off for a much longer period than it is on. Thus, class "C" operation is achieved, determined by base leak bias. The operation class, naturally determines the amount of feedback available to the tank.

Since the feedback signal is taken from the emitter, a 180 degree phase shift is not required for regenerative feedback. Of the remaining components, C4 is a coupling capacitor and R3 is used to vary the amplitude of the output sine wave.

Very similar to the series fed Hartley oscillator, is the shunt fed Hartley. Refer to Fig. 9 for the schematic of this oscillator circuit. Since this oscillator works virtually identically to the series fed, no explanation will be detailed. The difference in the two oscillators lies in the fact that the tank circuit of the shunt fed Hartley is isolated from all DC current. It is, thus, the variation in voltage on the collector of the transistor which begins tank action. A 180 degree phase shift (effected by the inductors) is necessary for proper regenerative feedback.

THE COLPITTS OSCILLATOR:

When compared to the Hartley oscillator, the Colpitts is more stable. It, like the Hartley, may be tuned over a wide frequency range. Fig. 10 shows a schematic for the Colpitts oscillator. The operation of the Colpitts varies only slightly from the Hartley, and, as observed in the shunt fed Hartley, no DC current will flow in the tank circuit. Also significant are the split capacitors (capacitors centered around a ground tap). Tank action will begin oscillations when the varying AC voltage at the collector of Q1 is coupled to the bottom of the tank. For oscillations to be sustained, a 180 degree phase shift is necessary. In this oscillator, two separate inductors will be available to alter frequency (the frequency chosen will depend on the position of S1).

Since the inductors of the tank circuit are of different sizes, and, therefore, of different impedances, altering the switch position will affect the output impedance of Q1 which will alter the operating point of the transistor to such a degree that oscillations may be inhibited. To prevent this, variable resistor R3 will provide a means to correct any shift of the amplifier's operating point, ensuring optimum oscillations.

The Colpitts oscillator provides signals in the higher radio frequency range. At these higher frequencies, power may be lost due to interelectrode capacitance developed within the transistor at the PN junctions. The fields developed around the inductor (called an RF choke) help counteract this undesirable phenomenon, preventing loss of signal power. Another way of viewing the action of L3 is to note that it provides a high resistance to upper frequency signals and, thus, ensures that those signals are developed.

Although the amplifier operates class "C", a 360 degree wave will be observed at TP 5. This is the result of the expanding and collapsing fields around L3, and a more accurate display of Q1's operating level may be seen at the emitter where a somewhat distorted class "C" wave will be observed.

Oscillations begin when power is applied and Q1 is biased on, causing the collector voltage to drop in the negative direction. This change is coupled to the tank and oscillations commence. From this point the operation is similar to that of the series fed Hartley, to include base leak bias operation.

THE RC PHASE SHIFT OSCILLATOR:

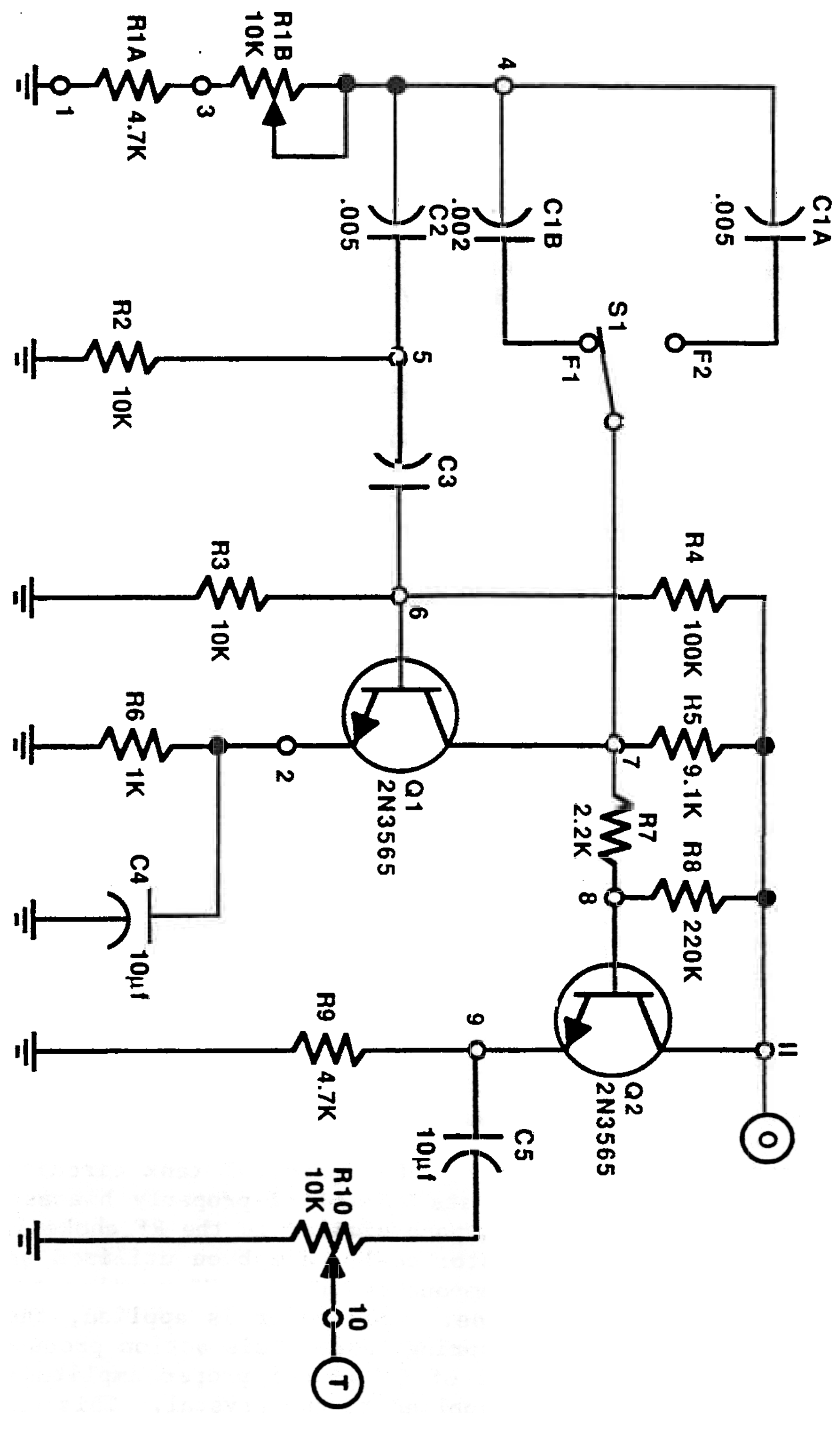
As already discussed, LC tanks are used to produce oscillations, sustained by regenerative feedback. The RC phase shift oscillator requires no tank for frequency development. As the name implies, a phase shifting network will be used for signal production. To understand this oscillator it will be helpful to introduce the concept of random noise.

Oscillations begin by any slight circuit variations in the collector or emitter voltage or as random noise. Every resistor in an oscillator circuit generates noise voltages, which are the products of the random motion of electrons induced by the applied voltage. In other words, each component may be thought of as a tiny voltage source producing an infinite range of frequencies. These random oscillations may include frequencies over 1000 Ghz.

When power is initially applied, the only signals in the system are noise generated. These signals are very small in amplitude and all have the potential to be equally amplified by the transistor. The amplified noise is introduced to the RC phase shift network. Positive feedback and, hence, oscillations will occur only at the frequency which will be shifted a total of 180 degrees. What frequency will be shifted is dependent on the size of the capacitors and resistors in the shifting networks. It may be stated, then, that the noise is selectively filtered by the phase shift network, allowing only that frequency which can provide proper feedback to be passed. In this circuit there are three shifting legs present. These are composed of C1A or C1B; R1B-R1A; C2 and R2; C3 and R3. Each leg must shift the phase of the signal by 60 degrees to obtain 180 degrees of shift. The output frequency may be altered by changing a component in one of the legs (in this case by selecting either C1A or C1B using switch S1).

Refer to Fig. 11 for the schematic of PC 37. Q1 is the amplifier while C1A or C1B: R1b and R1A; C2 and R2; C3 and R3 make up the feedback circuit and the frequency determining device. This FDD forms a capacitive circuit and current will lead applied voltage. The voltage drop across R1B-R1A is in phase with the current, therefore, this voltage will lead the applied voltage (by 60 degrees in this instance). A similar effect is observed at the remaining legs of the phase shift network for a total of three 60 degree phase shifts or 180 degrees of shift from the collector waveform. This produces the zero degree shift around the feedback loop necessary to sustain oscillations. The output frequency may be determined by utilizing S1, selecting one of two possible frequencies. The frequency may be determined by the formula f = .092/RC.

Q2 and associated components serve as a buffer. The purpose of a buffer is to ensure that a load placed on the oscillator's output does not draw significant amounts of current from Q1 which might dampen oscillations. Instead, the base of Q2 draws a very small current from the collector of Q1 and, thus, Q2, provides the majority of current to the load. Finally, R10 provides a means to adjust the output amplitude.



RC PHASE SHIFT OSCILLATOR PC 37

CRYSTAL OSCILLATOR:

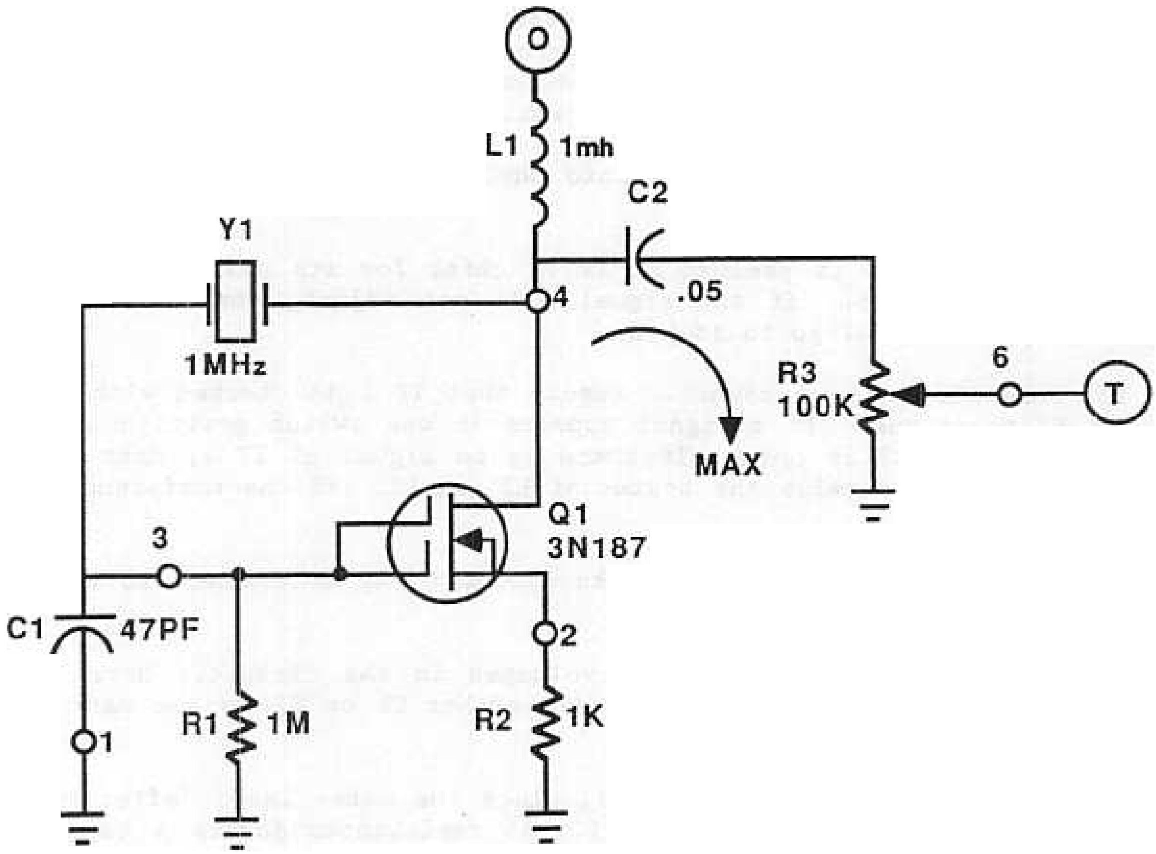
Oscillators dependent on resistors, capacitors, and inductors to perform frequency determining functions are subject to a common malady. As the components age, tolerances change, causing the desired frequency to change or drift. Changes in the ambient temperatures may also cause drift. When drift cannot be tolerated, a crystal controlled oscillator is used. The frequency drift of a crystal oscillator is extremely minute and watches of this type may take up to 300 years to lose a second. Crystal oscillators are the standard means used for maintaining the carrier wave transmissions of radio stations within the limits designated by the FCC. Crystals are the active element in high-fidelity microphones, loud speakers, and electric pickup arms.

The characteristic of piezoelectricity or the piezoelectric effect is the property of a crystal by which mechanical stresses produce electric charges on the crystal surface, and, conversely, electric charges applied to the crystal produce mechanical stresses, If an AC voltage is applied to a crystal, it will vibrate at the frequency of the applied voltage. The amplitude of vibration, however, is much greater for a given crystal a certain frequencies than at others. These are the resonant frequencies of the crystal, and are determined by the way the slab is cut from the parent crystal as well as the slab's thickness. The thinner the crystal, the higher the frequency. Quartz crystals are the preferred choice of industry as they commonly occur in nature, are, thus cheap, and are fairly strong, mechanically. A crystal will commonly resonate at more than one frequency due to variations in slab thickness.

The crystal is cut and mounted to vibrate most strongly at one of its resonant frequencies, usually the lowest called the fundamental frequency. Higher resonant frequencies called overtones are almost exact multiples of the fundamental frequency. The maximum fundamental frequency will be 10 Mhz and is limited by how thin the crystal slab may be sliced without cracking when it vibrates. Higher frequencies are possible using overtones (up to 100 Mhz). The crystal is current limited, for if too high a current is applied to the crystal it will scorch and burn.

The vibrating crystal is equivalent to a parallel/series resonant circuit and serves as the FDD in the oscillator circuit. Refer to Fig. 12 for the schematic of PC 50. The frequency is determined by the fundamental frequency of the crystal. As displayed, this oscillator is not tunable but can be made so by the addition of a parallel tank circuit resonating at the desired overtone. Components R1 and R2 properly biases the dual gate MOSFET, Q1 and L1 serves a purpose similar to the RF choke in the Colpitts oscillator. A bipolar transistor could have been utilized as the amplifier with the proper biasing components added. C2 couples the signal to R3 which is variable for amplitude. When power is applied, the crystal will bend between the plates and spring back. This action produces an AC voltage which is sent to the input of Q1 at the proper amplitude and phase to be amplified by the FET and applied to the crystal. This causes the crystal to vibrate at its fundamental frequency and oscillations are sustained through subsequent feedback action.

C1 serves to eliminate undesirable high frequency harmonics from the feed-back loop which might otherwise distort the output signal.



CRYSTAL OCS PC50

TROUBLESHOOTING

Now that oscillator operation has been explained, there remains the task of malfunction location. Theoretical troubleshooting will be explained, followed by some practical exercises. First to be discussed will be the Hartley oscillator. The procedures outlined will produce maximum results in the least time if precisely followed.

The procedures may be divided into three main steps. Refer to figure 8.

1. If an output is present at TP 7, check for its ability to adjust the signal amplitude. If the signal will not adjust, check R3. If no signal is present TP 7 go to step 2.

2. Check TP 2 for a signal. Ensure that TP 2 is checked with S1 in F1 <u>and</u> F2 positions. If a signal appears in one switch position but not the other, C1 or C2 is open. If there is no signal at TP 2, make resistance checks to determine the status of L1 and L2. If the resistances are normal, go to step 3.

3. Make voltage/resistance checks around Q1 to determine faulty component.

Below are examples of "normal" voltages in the circuit. Note: two frequencies are possible using S1 to add either C1 or C2 to the tank circuit.

When the tank circuit is checked, place the meter leads (after removing trainer power) from TP 2 to TP 1. As resistances across a capacitor are infinite, the meter should indicate the small resistance across L1 and L2 coils. If an infinitive condition is registered, either L1 or L2 is open. To determine the faulty component, move the lead from TP 1 to TP 4. If a small resistance is measured, L1 is good. Remove the lead from TP 2 to TP 1. This checks L2 in the same manner as L1 was checked.

It is not possible to check either C1 or C2 for an open condition with the DMM. If, however, either capacitor is short, this condition will register on the DMM. An open capacitor is indicated if there is a signal at TP 2 in one switch position but not the other. If the tank circuit is good, the problem lies in the amplifier or surrounding components.

F1 = 31.25 KHZ maximum signal amplitude is 20 V peak to peak.

F2 = 22.73 KHZ maximum amplitude is 15 V peak to peak.

Q1 Collector: 9.81 vdc, Base: 1-42 vdc, Emitter: .076 vdc

MALFUNCTION ONE
HARTLEY OSCILLATOR

S1 CENTER

1. Measure the AC AT TP 7. A signal is present

2. Check R3 to determine if it will adjust the output signal amplitude. Result: R3 has only a slight affect on the output amplitude.

3. Make a resistance check from TP 6 to ground. Result: infinity.

Conclusion: R3 is open.

MALFUNCTION TWO
HARTLEY OSCILLATOR

S5 CENTER

1. Check TP 7 for an output signal. Result: No signal.

2. Check TP 2 with oscilloscope. Make the check in both switch positions. F1: No signal, F2: No signal.

3. Check the tank circuit. Resistance checks are made at this time. TP 2 to TP 1 will indicate infinity. TP 2 to TP 4 also indicates infinity.

Conclusion: L1 is open

MALFUNCTION THREE
HARTLEY OSCILLATOR

S3 CENTER

1. Check TP 7 with the o'scope. Result: No signal.

2. TP 2 is, then, checked with the o'scope. Result: No signal.

3. Make the resistance checks of the tank circuit. Result: TP 2 to TP 4 is normal at 36 ohms. TP 4 to TP 1 is normal at 36 ohms.

4. Check DC volts around Q1. Results: TP 5 = 11.94 vdc, TP 3 = .593 vdc, TP 4 = .0017 vdc. The collector voltage increased to applied. The base voltage increased slightly, and the emitter voltage decreased significantly.

5. Since the transistor is not reacting properly to the base voltage it can reasonably be concluded that the transistor is the faulty component. Resistance checks around

the transistor is made. Results: From TP 3 to TP 5 reads infinity. Switching leads at the same points also gives an infinity reading. The front to back ratio of the base emitter junction is then measured with normal indications.

Conclusion: Q1 collector is open.

COLPITTS OSCILLATOR

The same procedures may be used to troubleshoot the Colpitts oscillator as only the tank circuit configuration differs. Below are three examples of troubleshooting and some "normal" circuit voltages. Refer to figure 10.

NORMAL VOLTAGES
COLPITTS OSCILLATOR

F1 position:	45.4 KHZ	TP 5:	11.81 vdc
F2 position:	26.3 KHZ	TP 4:	-2.41 vdc
		TP 6:	.677 vdc

S1 CENTER

1. Check for a signal at TP 8. No signal is present.
2. There is no signal at TP 3 in either F1 or F2 positions.
3. The tank circuit is checked as follows. TP 3 to TP 2 in F1 position is 36 ohms and is normal. In position F2 the resistance is 89 ohms and is normal.
4. The next step is to check the DC around the transistor. TP 5 is 11.80 vdc and is above normal. TP 4 is + 4.85vdc and has increased. TP 6 is 4.40vdc and is above normal. Remember that if the DC voltage increases, look down. In this case the emitter, as well as everything else, has increased so we first look below TP 6.
5. The resistance from TP 6 to TP 1 is checked and is 2.92 K ohms. This indicates R2 and R3 are present but will R3 adjust?
6. Attempt to adjust R3 and determine if the resistance changes. No change is indicated.

Conclusion: R3 wiper is open.

MALFUNCTION TWO
COLPITTS OSCILLATOR

S1 UP

1. Check TP 8 with the o'scope. Result: No signal.
2. TP 3 is next checked and no signal is observed in either switch position.
3. The tank circuit is next checked for proper resistances and found to be normal from TP 3 to TP 2.
4. TP 3 to ground is normal.
5. Resistance from TP 2 to ground is .001.

Conclusion: C2 is short.

MALFUNCTION THREE
COLPITTS OSCILLATOR

S6 UP

1. Check TP 8, no signal is present.
2. There is a signal present at TP 3 in both F1 and F2 positions. The tank and amplifier circuits must be operating normally.
3. Check TP 7 with the o'scope and adjust R4 both fully clockwise and counter clockwise. With R 4 clockwise, the wiper arm is at the top of the resistor and the signal which should be maximum is lost.
4. Check the wiper arm of R4 for a short to ground. TP 8 to ground indicates a short.

Conclusion: R4 wiper arm is shorted.

MALFUNCTION EXAMPLE
RC PHASE SHIFT OSCILLATOR

NORMAL VOLTAGES

Set R1B fully CW.
F1: 1.66 Khz

TP 7	7.81 VDC	TP 6	1.065VDC	TP 9	7.17 VDC
TP 2	.461VDC	TP 8	7.82 VDC		

F2: 1.25 Khz
Note: Refer to Fig. 11

1. Check TP 10 with the O'scope. Result: No signal.

2. Check TP 7 with the O'scope. Result: No signal.

3. Check TP 7 and measure the DC present. Anything over 7VDC but less than 8 VDC indicates a normally operating transistor. Any slight change is due to the absence of a signal. Result: 7.77 VDC. OK.

4. The next step is to check the phase shift net work. To do this all power must be removed from the trainer and the function generator set for a 1 KHZ square wave. The amplitude is not that critical as long as a wave form is observable. Use DMM leads to inject the signal, if possible. Inject the square wave at TP 5 and observe TP 6 with the o'scope. If everything is normal, a differentiated wave form should be present. If a distorted square wave is seen the capacitor is good but the resistor in that phase shift leg is open. If nothing is seen either the capacitor is open or the resistor is shorted to ground. Result: A differentiated wave is present at TP 6.

5. Inject a signal at TP 4 and check TP 5 with the o'scope. Result: A differentiated wave is present at TP 5.

6. Inject a signal at TP 7 and observe TP 4 with the o'scope. Result: A distorted square wave is present at TP 4. This could mean either R1B or R1A is open. Resistance checks indicates R1B to be the faulty component.

MALFUNCTION EXAMPLE
CRYSTAL OSCILLATOR

NORMAL VOLTAGES

Set R3 maximum CW. The o'scope should indicate approximately 18 Vp/p. Frequency is about 2 MHZ. Refer to Fig. 12.

TP 4 11.95 VDC TP 2 .945 VDC TP 3 8 Vp/p TP 4 20 Vp/p

1. Check TP 6 with the o'scope. Result: No signal.

2. Check TP 4 with the o'scope. Result: No signal.

3. Check TP 4 with the DMM. Result: 11.64 VDC.

4. Check TP 3 with the DMM. Result: .0447 VDC.

5. Check TP 2 with the DMM. Result: 11.64 VDC

Conclusion: Since the same voltage appears at both TP 4 and TP 2 it may be concluded that there exists a drain to source short. This is confirmed by making a resistance check from TP 4 to TP 2.

SUMMARY:

During the previous four hours of conference the four basic types of oscillators have been discussed. The oscillators included the Colpitts, Hartley, Phase-shift, and the Crystal oscillators. The instructor will briefly review each oscillator circuit using the appropriate slides.